Hydrogen Amperometric Gas Sensor: Performance Evaluation by SSTUF

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Introduction:
New fuel cell technologies are being developed for optimal energy conversion efficiencies and environmental protection. Sensors are required for monitoring in the fuel feed, environmental and personal safety, and for feedback controls [1, 2]. A workstation, the Shared Sensor Technology User Facility (SSTUF) (Fig.1), capable of mimicking the fuel cell operating environment was developed in order to test our sensors as well as those of any other manufacturer, developer, or user [3]. The SSTUF system can be pressurized to gauged pressures of 3 atm (45 psig) and higher, while simultaneously maintaining flow and gas composition control using four calibrated mass flow controllers. The mass flow controllers generate mixtures to three target gases besides the matrix (air, nitrogen, or premix background) at the flow rate from 50 cc/min to 2000 cc/min. Temperature control (ambient-450^{o}C) and humidity control (0-100% RH) are also achievable.

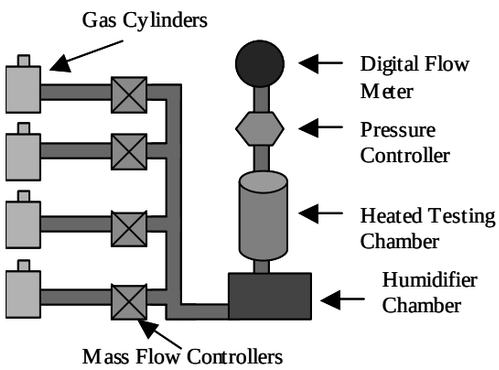

Figure 1: Schematic of the SSTUF pneumatics. Sensors & controls are connected to a PC equipped with National Instrument DAQ system for automatic operation and data collection.

An electrochemical cell with porous working and counter electrodes and a Nafion®-coated Ag/AgCl reference electrode was developed for the application of hydrogen safety sensors and gas stream monitoring [2]. The sensor performance was evaluated at 1, 2, and 3 atm. Assuming an ideal gas model, the partial pressure of hydrogen in the gas mixture is proportional to the total pressure and at a higher total pressure a greater concentration gradient across the gas permeable membrane in the sensor will be present. This will induce a higher flux of H_2 to the sensing electrode and a higher current or signal. Data shown in figure 2a and 2b support this simple model of the sensor. It is interesting to note that the background signal remained almost constant with pressure.

The hydrogen electro-oxidation reaction on the Pt working electrode is $H_2 + ½\ O_2 \rightarrow H_2O$, which states that oxygen is required in the hydrogen sensor. In order to find out the limiting oxygen level for operation, the sensor was tested under different oxygen levels (16.8 to 0%). The hydrogen sensitivity decreased by about 10% as the oxygen level went from 16.8% to 0% (Fig.3). The electrolyte in the sensor is 30% H_2SO_4, and oxygen dissolves in the electrolyte.

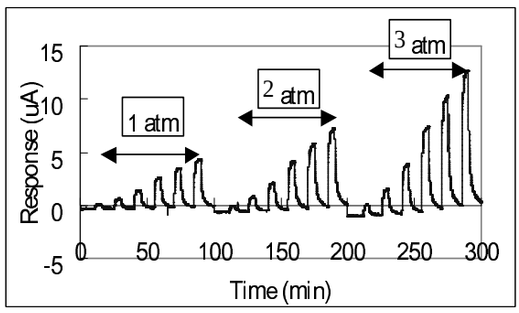

Figure 2a: Typical sensor response at 0, 5, 10, 20, 40, 60, 80% H_2 in air at different pressures.

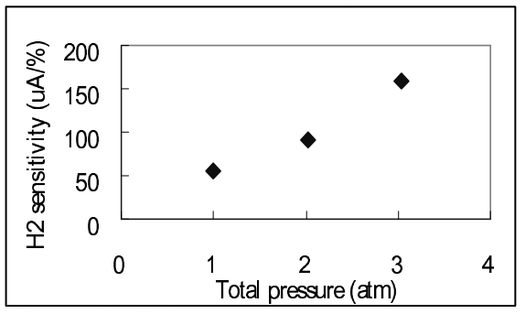

Figure 2b: Hydrogen sensitivity at various total pressures. The hydrogen sensitivity is linearly proportional to the total pressure with an R^2 value of 0.971 at 1, 2, and 3 atm.

According to the Henry's Law, the oxygen concentration in the electrolyte decreases as the oxygen level in the gas mixture goes down. Lower H_2 oxidation rate results in a lower sensor signal. This effect is <10% during a five-minute exposure but can eventually eliminate the sensor signal at very long exposure times. Additional characterization is planned for this sensor in the IIT SSTUF.

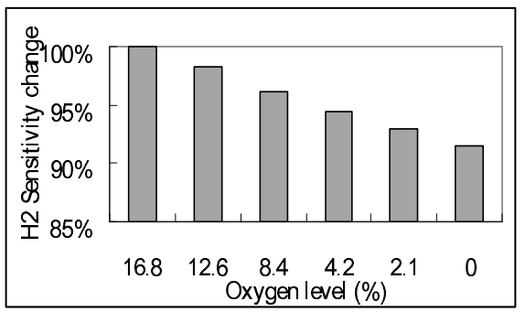

Figure 3: The sensitivity of hydrogen dropped less than 10% as the oxygen level in the gas mixture decreased from 16.8% to 0%.

Acknowledgements:
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References:
1. R. S. Glass, J. A. Milliken, K. Howden, and R. Sullivan (ed.) *Report: Sensor Needs and Requirements for Proton Exchange Membrane Fuel Cell Systems and Direct Injection Engines,* Lawrence Livermore National Laboratory, Livermore, California, May 2000.

2. Y. Chao, W.J. Buttner, S. Yao, and J.R. Stetter, *Amperometric Sensor for Selective and Stable Hydrogen Measurement*, submitted to Sensors & Actuators B [2004 in submission].

3. SSTUF apparatus developed out of the DOE CARAT program and is available to any user. Developed by members of the IIT Sensor Research Group, more details are available at http://www.iit.edu/~stetter/SSTUFOverview.html